HCAT PROJECT

FUNCTIONAL ROD/SEAL TESTING AND QUALIFICATION OF HVOF COATINGS ON NAVY ACTUATORS

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NAS Patuxent River, MD

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Report Documentation Page

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15. SUBJECT TERMS

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Phase II Rod/Seal Test Status

- HCAT Joint Test Protocol (JTP) objective is to validate HVOF thermal spray coatings as acceptable replacements for hard chrome plating on hydraulic/pneumatic actuators.

- Phase II test based on HCAT JTP, dated 30 Sept 2003, was modified to include:
    - High Temp at 275°F (not 300°F)
    - MIL-PRF-83282 Fluid Used (not MIL-PRF-87257)
    - Cycling rates/times modified to achieve same total cycles.

- Functional Rod/Seal Testing at PAX Hydraulic Lab is Complete.
    - Pre-test and post-test rod traces were provided by Supfina.
    - Rod and seal pictures provided by NAVAIR Materials.

JTP Details

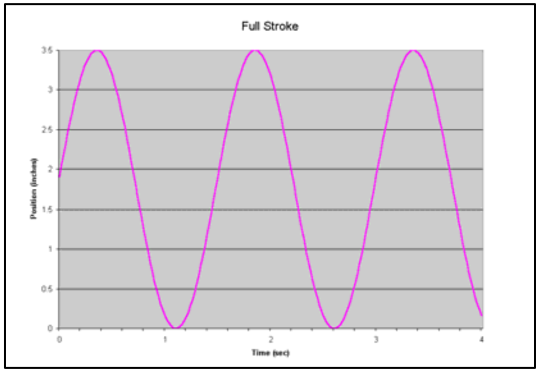
1. Evaluate eight different rod coatings with one basic seal configuration.
    - Each rod will be inspected and characterized before and after testing (optical microscopy and surface profilometry).
    - Hydraulic fluid leakage from each block will be measured and recorded.
    - Seals inspected for unusual wear.
2. Testing for 12.5 days to total over 1 million cycles of full, super-imposed dither, and dither stroke cycles.
3. Hydraulic fluid viscosity, chlorine and water content checked.
4. Block dimensions checked at JAX prior to testing.

Test Apparatus

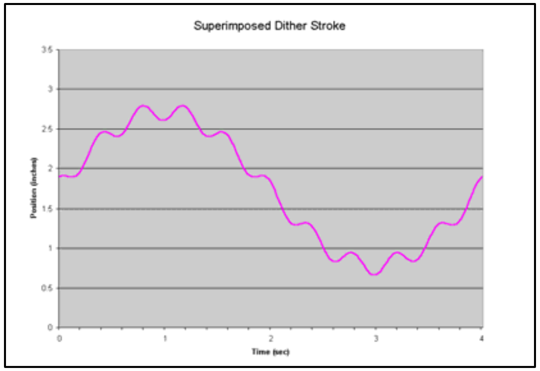
- Located at NAVAIR Patuxent River Hydraulic Lab.
- Master hydraulic piston drives four test rods. Each rod passes through two blocks ("Back End Block" and "Far End Block").
- Apparatus is mounted inside an environmental chamber capable of maintaining a temperature between -65° and +300°F.
- The master piston passes through a sealed port on the environmental chamber.
- The hydraulic power supply is located outside the chamber for increased reliability of test hardware. Constant hydraulic pressure is applied on seals.
- Hydraulic lines to the fixture are single-ended and thus should not heat or cool the test hardware.

Stroke Profile

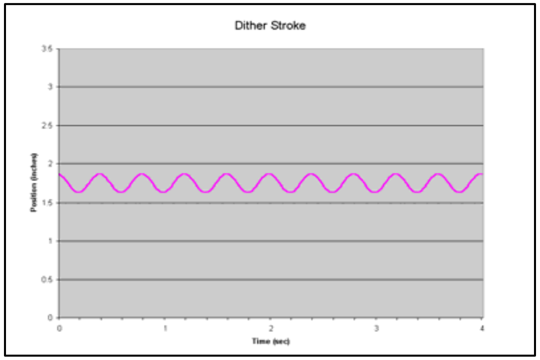
• Full Stroke (3.5" Stroke, 1.3 second Period, 15 Minute Duration per Hour)



• Superimposed Dither (2" Main Stroke, 0.25" Dither stroke, 2.4 second Period, 3 Hz Frequency, 21 Minute Duration per Hour)



• Dither (0.25" Dither stroke, 3 Hz Frequency, 24 Minute Duration per Hour)



Temperature Profile

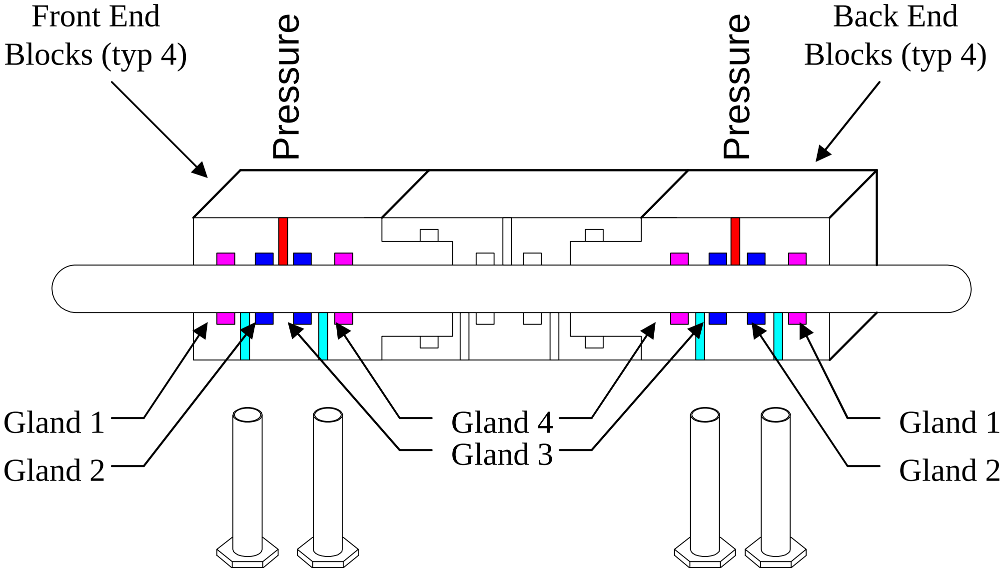
Temp (°F)	Hours	Cycles
160	70	645,187
200	14	129,037
225	14	129,037
250	23	211,990
275	23	211,990
- 40	5	46,085
totals	149	1,373,326

Note: Prior to each test day temperature shall begin at 0°F to evaluate static leakage at startup.

Test Rod and Seal Layout

• One seal configuration used in each of the 8 blocks. The 4 rod halves allow 2 data points per rod/seal configuration.

• Primary position (test seals) indicated in blue and the secondary (scraper seals) in magenta. Primary and secondary seals are similar.



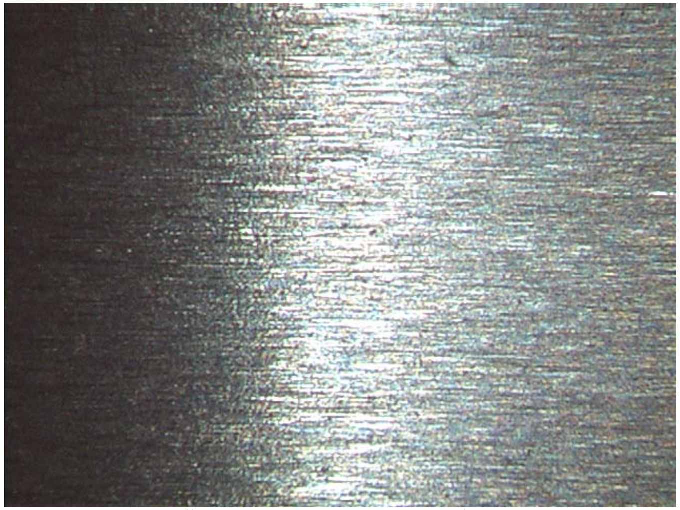
SEAL CONFIGURATION	SUPPLIER
MIL-P-83461 O-ring w/ 2 backup rings	Greene Tweed

Rod No.	Material Coating	Finish Process
6a	WC/CoCr (86/10/4)	Coarse Stone, As-Ground
6b	WC/CoCr (86/10/4)	Fine Stone, As-Ground
8a	WC/CoCr (86/10/4)	Film, Superfinish
8b	WC/CoCr (86/10/4)	Stone, Superfinish
9a	WC/CoCr (86/10/4)	Film, Superfinish
9b	WC/CoCr (86/10/4)	Stone, Superfinish
11a	WC-Cr3C2-Ni (73/20/7)	Film, Superfinish
11b	WC-Cr3C2-Ni (73/20/7)	Stone, Superfinish

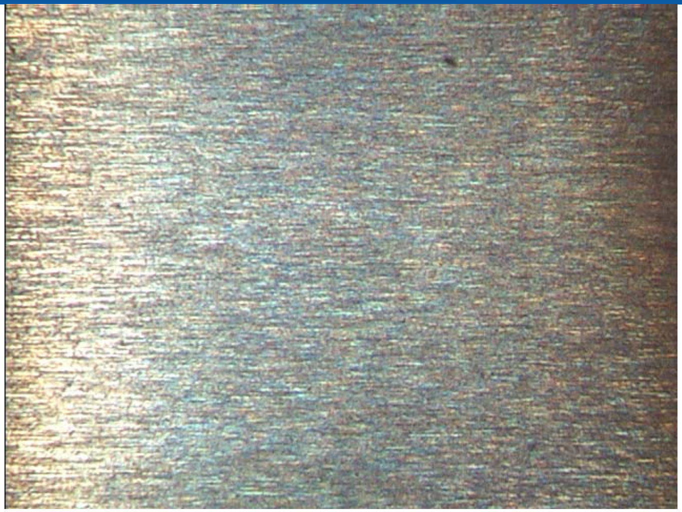
Rod Half	Material Coating	Pre-Test Surface Finsh (Ra, Rp, Rz, Rsk, Tp)	Post-Test Surface Finsh (Ra, Rp, Rz, Rsk, Tp)
6a	WC/CoCr (96/10/4)	11.1, 42.7, 92.2, -1.1, 87%	10.7, 38.5, 58.6, -0.4, 8.7%
6b	WC/CoCr (96/10/4)	3.5, 10.6, 26.5, -.06, 88%	3.0, 9.1, 16.7, -1.1, 59%
8a	WC/CoCr (96/10/4)	2.4, 7.4, 37.2, -5.4, 85%	2.1, 6.4, 13.9, -3.9, 85.2%
8b	WC/CoCr (96/10/4)	1.8, 7.1, 17.8, -2.2, 86%	2.0, 5.4, 9.8, -6.5, 89.6%
9a	WC/CoCr (96/10/4)	1.4, 4.4, 24.3, -5.8, 87%	1.4, 4.2, 9.3, -4.2, 94.6%
9b	WC/CoCr (96/10/4)	2.1, 6.3, 24.8, -3.1, 84%	1.8, 6.6, 9.0, -2.8, 91.5%
11a	WC-Cr_3C_2-NiCr (86/1	2.9, 8.3, 37.8, -3.7, 84%	2.0, 6.5, 15.8, -5.6, 90.6%

Rod Half	Test Gland	Material Coating	Final Surface Finish (Ra, Rp, Rz, Rsk, Tp)	Finish Process	Culmulative Leakage	Ranking
8b	BE2-C,	WC/CoCr (86/10/4)	1.8, 7.1, 17.8, -2.2, 86%	Stone, Superfinish	27.0	Best
11a	FE4-B	$WC-Cr_3C_2-Ni$ (73/20/7)	2.9, 8.3, 37.8, -3.7, 84%	Film, Superfinish	29.4	Best
9a	FE3-B	WC/CoCr (86/10/4)	1.4, 4.4, 24.3, -5.8, 87%	Film, Superfinish	30.2	Best
8a	FE2-B	WC/CoCr (86/10/4)	2.4, 7.4, 37.2, -5.4, 85%	Film, Superfinish	32.8	Best
8b	BE2-D	WC/CoCr (86/10/4)	1.8, 7.1, 17.8, -2.2, 86%	Stone, Superfinish	35.6	Medium
9b	BE3-D	WC/CoCr (86/10/4)	2.1, 6.3, 24.8, -3.1, 85%	Stone, Superfinish	38.8	Medium
6b	BE1-D	WC/CoCr (86/10/4)	3.5, 10.6, 26.5, -0.6, 88%	Fine Stone, As-Ground	40.6	Medium
8a	FE2-A,	WC/CoCr (86/10/4)	2.4, 7.4, 37.2, -5.4, 85%	Film, Superfinish	43.0	Medium
11a	FE4-A,	$WC-Cr_3C_2-Ni$ (73/20/7)	2.9, 8.3, 37.8, -3.7, 84%	Film, Superfinish	46.0	Medium
9b	BE3-C,	WC/CoCr (86/10/4)	2.1, 6.3, 24.8, -3.1, 85%	Stone, Superfinish	48.2	Medium
6b	BE1-C,	WC/CoCr (86/10/4)	3.5, 10.6, 26.5, -0.6, 88%	Fine Stone, As-Ground	51.6	Medium
9a	FE3-A,	WC/CoCr (86/10/4)	1.4, 4.4, 24.3, -5.8, 87%	Film, Superfinish	53.6	Medium
11b	BE4-D	$WC-Cr_3C_2-Ni$ (73/20/7)	2.8, 5.5, 54.2, -6.7, 81%	Stone, Superfinish	65.0	Worst
11b	BE4-C,	$WC-Cr_3C_2-Ni$ (73/20/7)	2.8, 5.5, 54.2, -6.7, 81%	Stone, Superfinish	67.4	Worst
6a	FE1-B	WC/CoCr (86/10/4)	11.1, 42.7, 92.2, -1.1, 87%	Coarse Stone, As-Ground	71.4	Worst
6a	FE1-A,	WC/CoCr (86/10/4)	11.1, 42.7, 92.2, -1.1, 87%	Coarse Stone, As-Ground	85.6	Worst

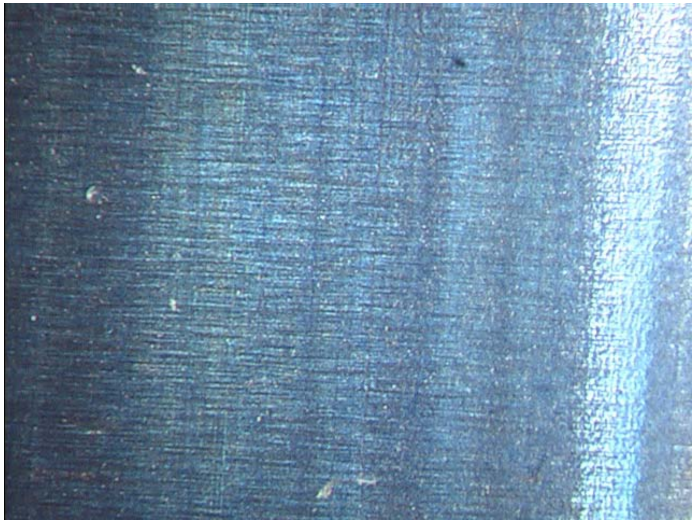
Rod #6



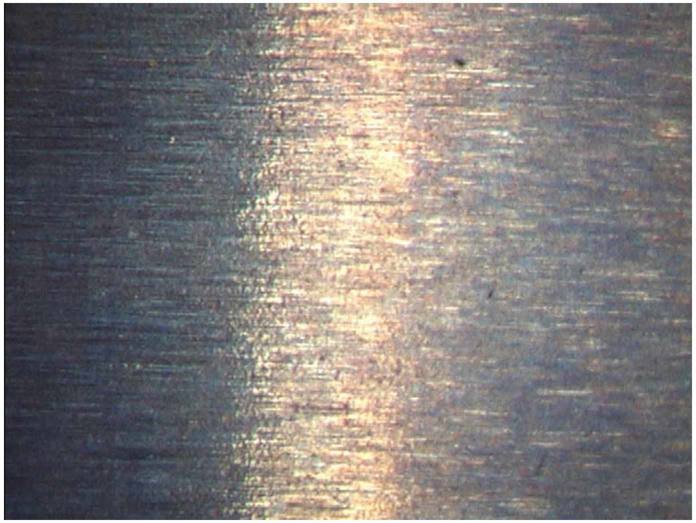
Rod 6a - Pre-Test (100x)



Rod 6b - Pre-Test (100x)

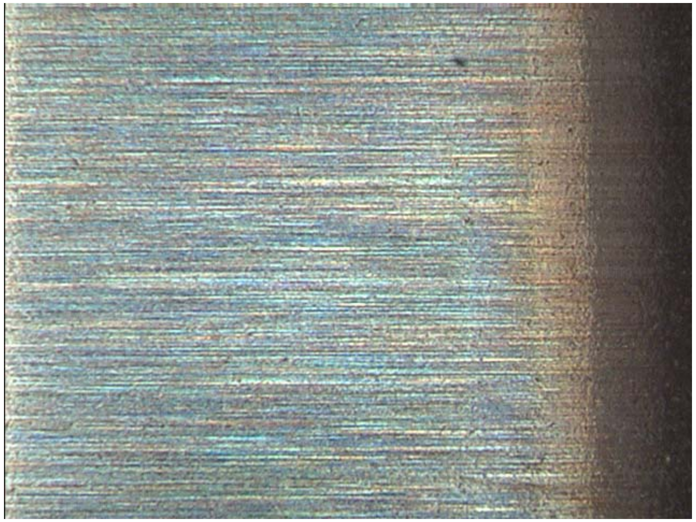


Rod 6a - Post-Test (100x)

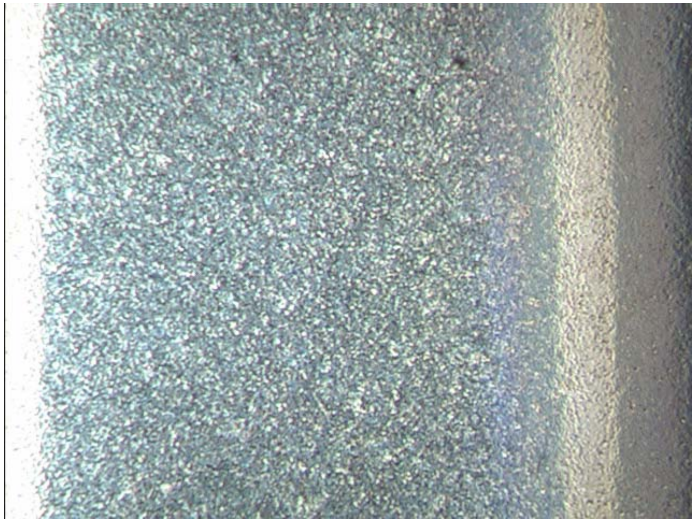


Rod 6b - Post-Test (100x)

Rod #8



Rod 8a - Pre-Test (100x)



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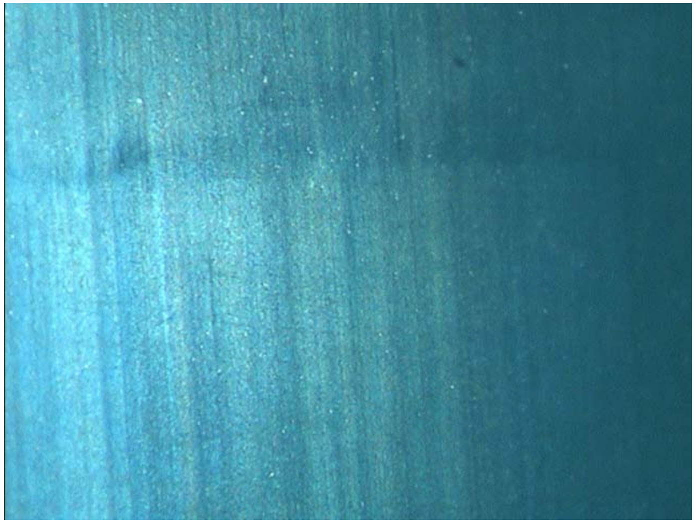

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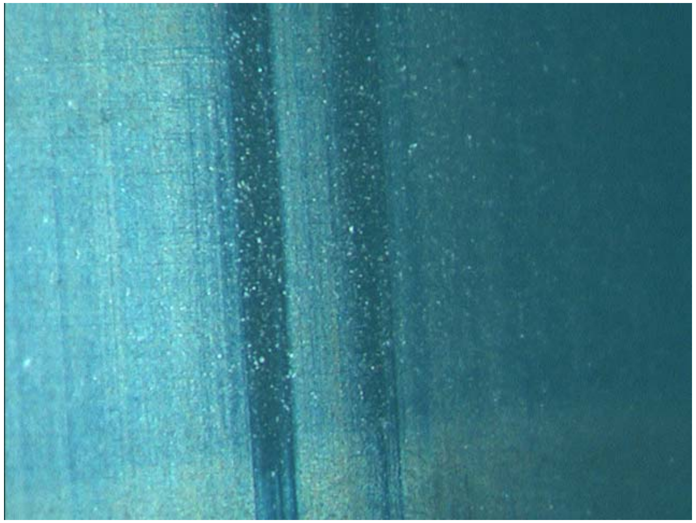
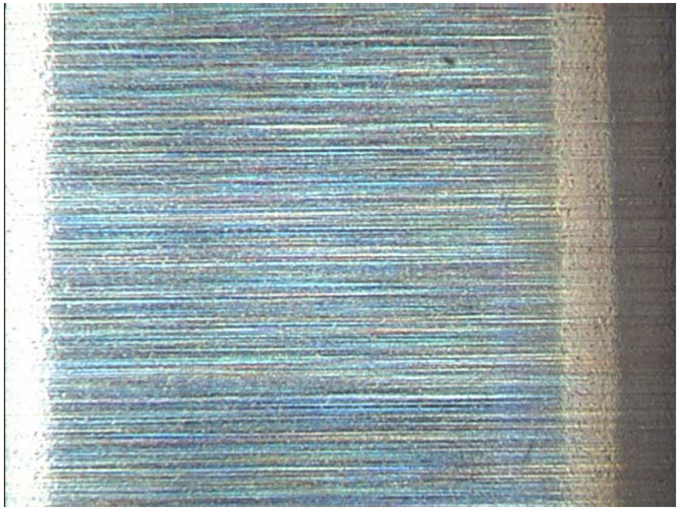
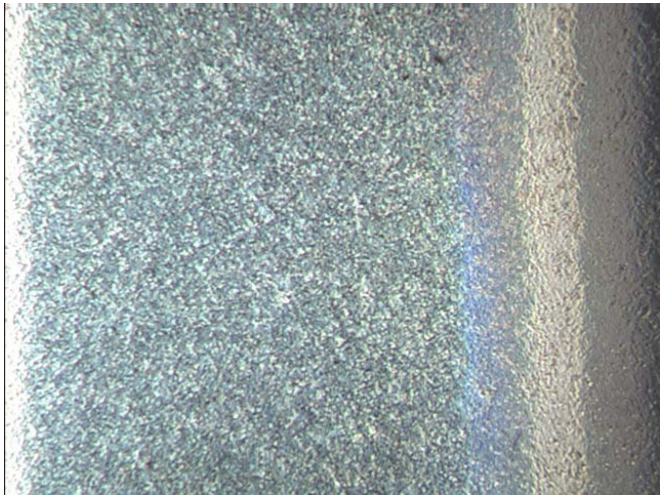


Rod 8b - Post-Test (100x)

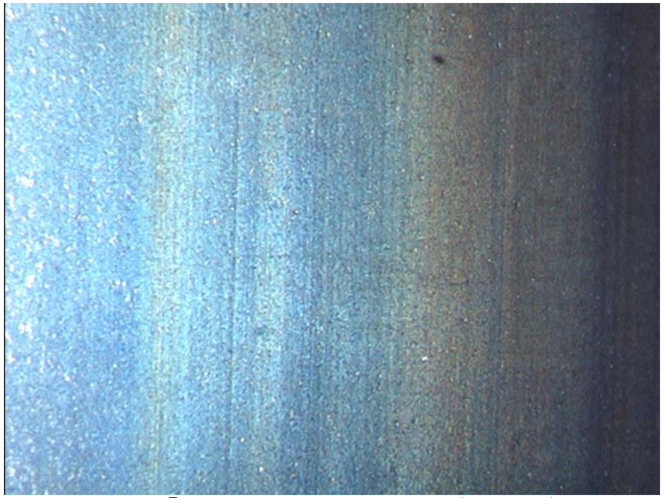
Rod #9



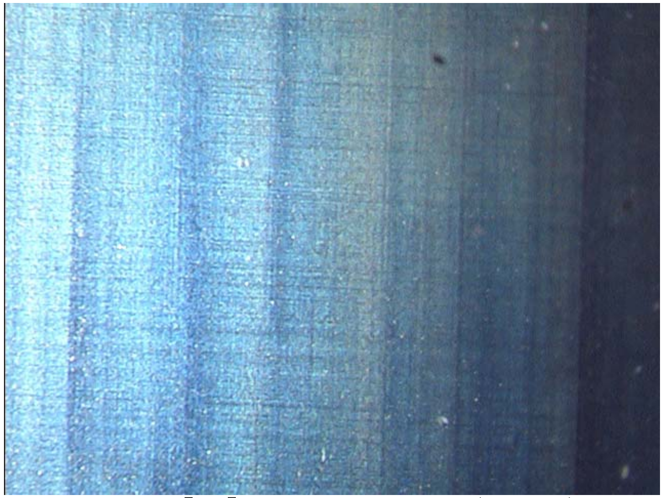
Rod 9a - Pre-Test (100x)



Rod 9b - Pre-Test (100x)

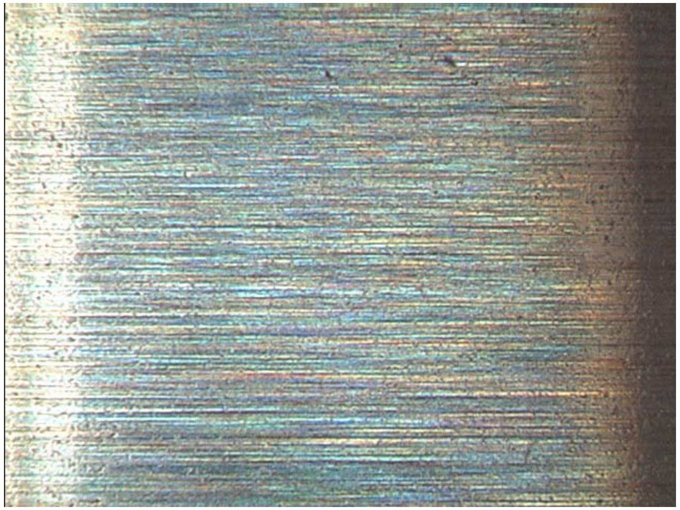


Rod 9a - Post-Test (100x)

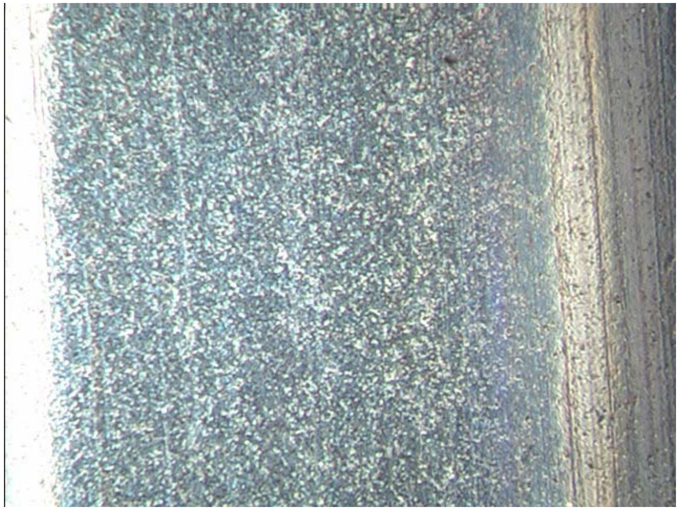


Rod 9b - Post-Test (100x)

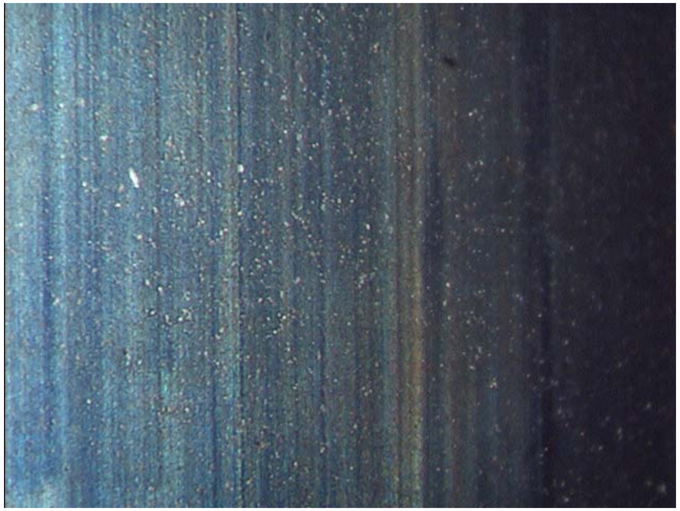
Rod #11



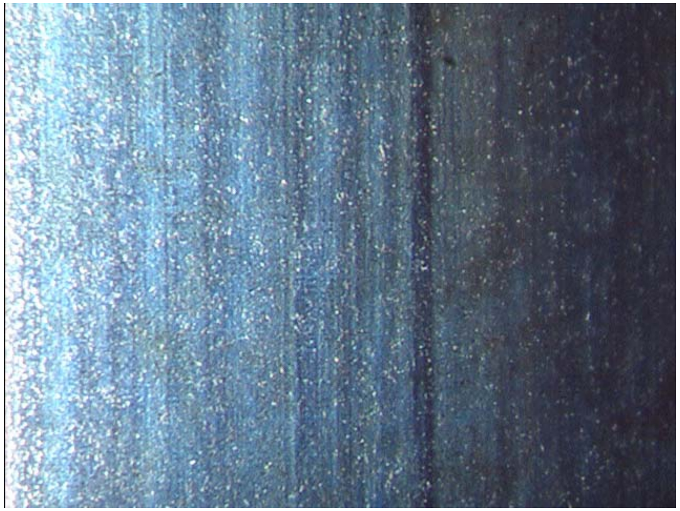
Rod 11a - Pre-Test (100x)



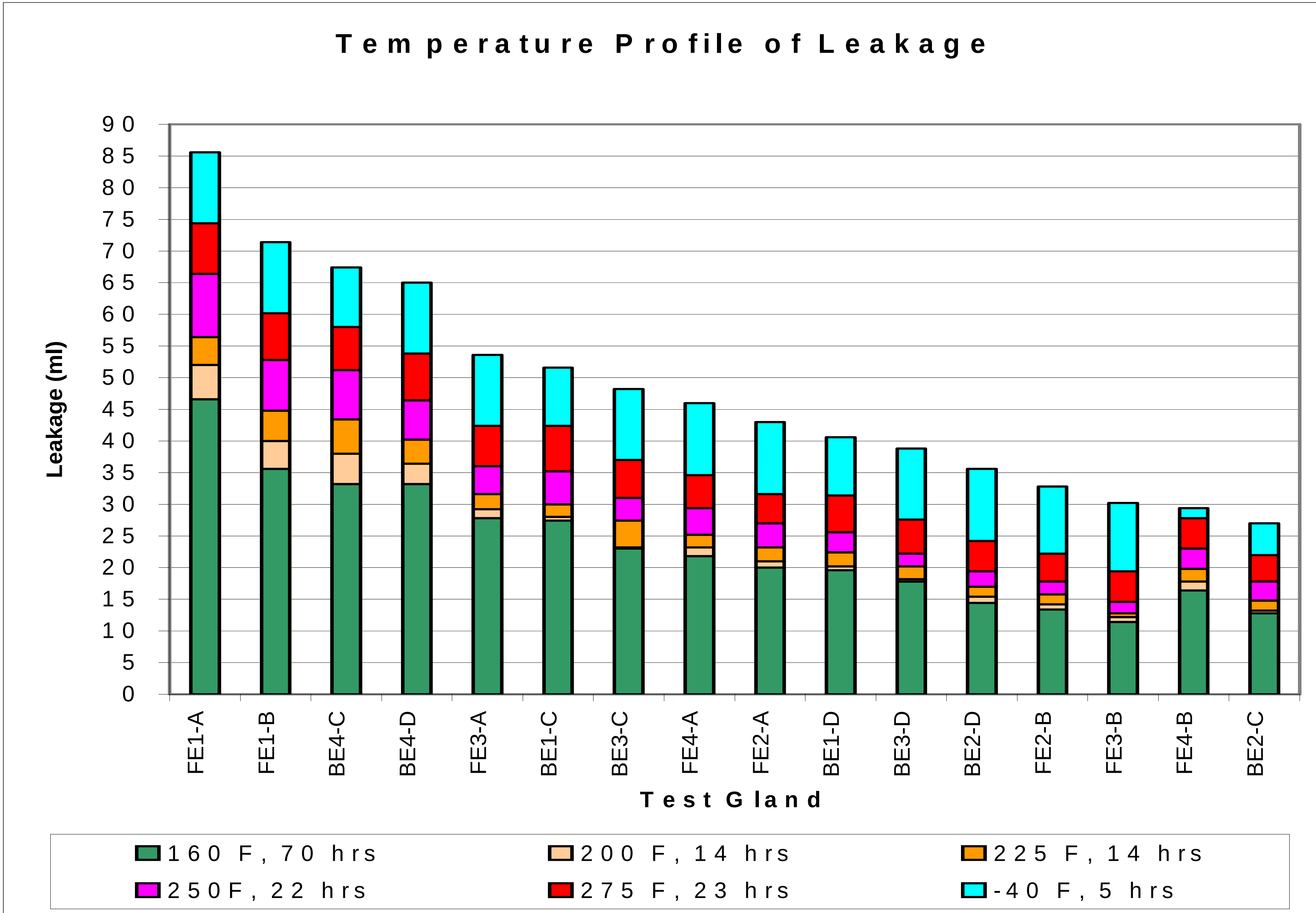
Rod 11b - Pre-Test (100x)



Rod 11a - Post-Test (100x)



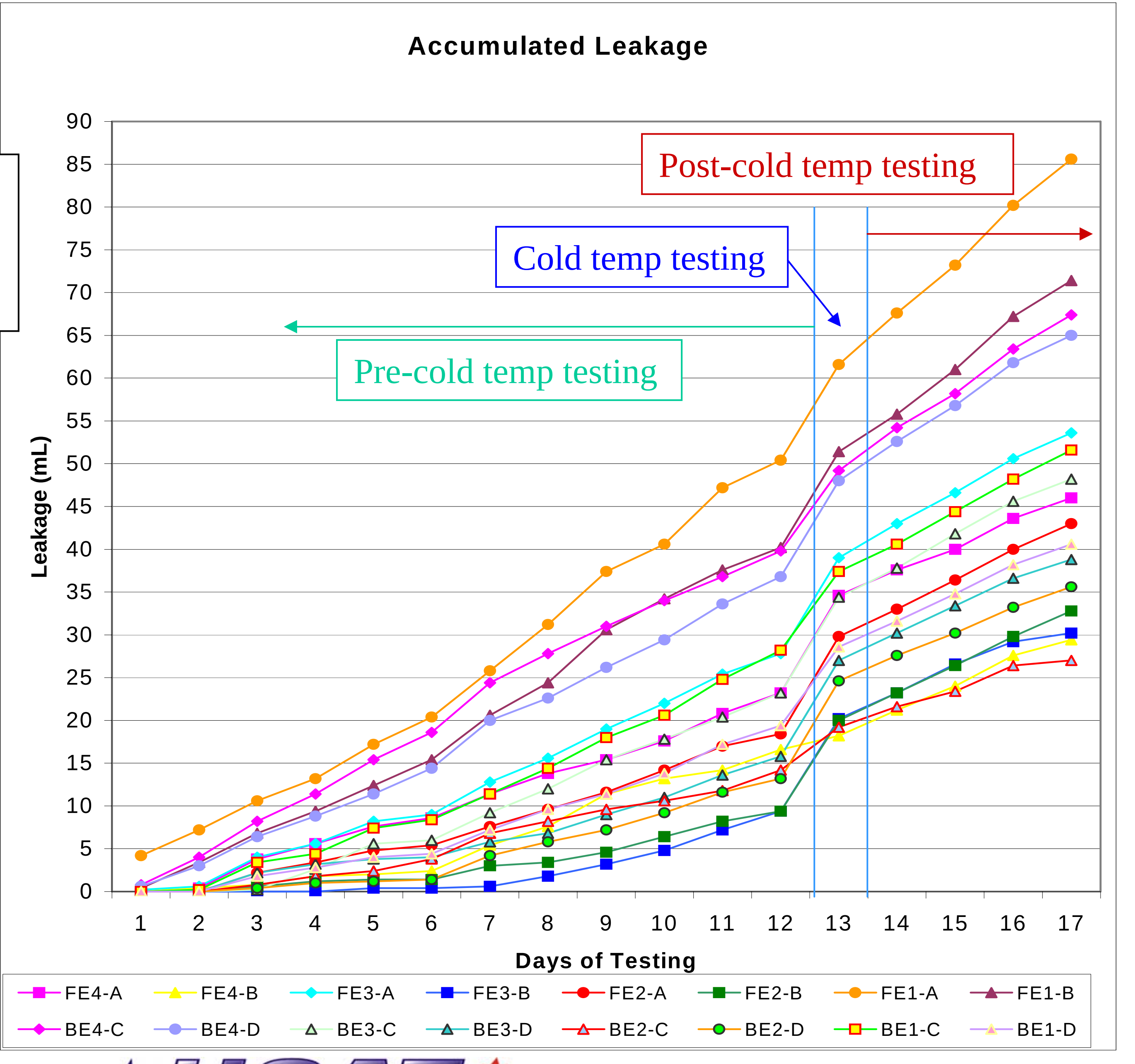
Rod 11b - Post-Test (100x)



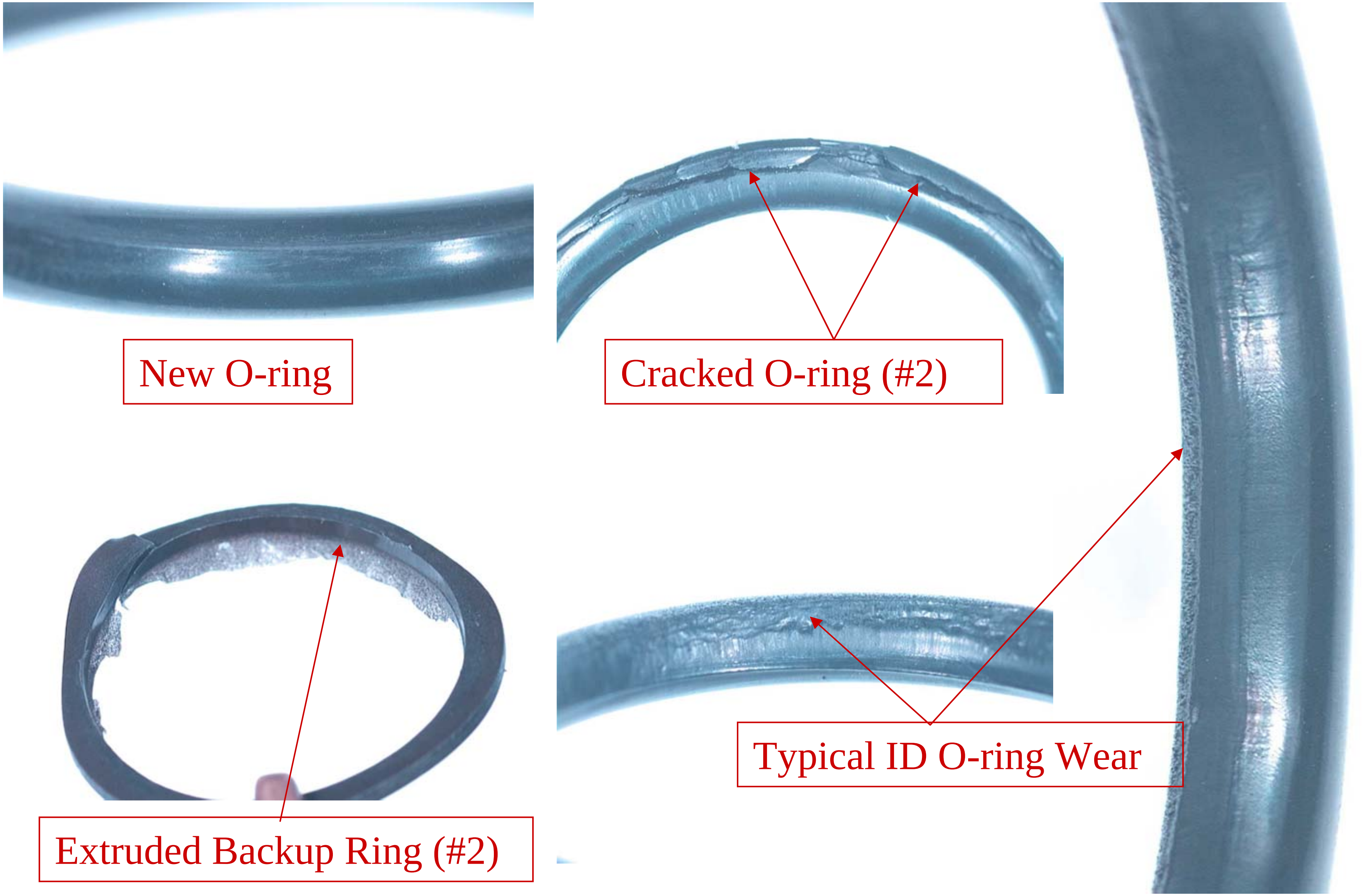
Temperature Profile of Leakage
Leakage (ml)
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
FE1-A
FE1-B
BE4-C
BE4-D
FE3-A
BE1-C
BE3-C
FE4-A
FE2-A
BE1-D
BE3-D
BE2-D
FE2-B
FE3-B
FE4-B
BE2-C
Test Gland
160 F, 70 hrs
200 F, 14 hrs
225 F, 14 hrs
250F, 22 hrs
275 F, 23 hrs
-40 F, 5 hrs

Post-cold temp testing had similar leakage rate to pre-cold testing.

Cold temp testing had higher leakage rate, as expected.



Seal Wear



HCAT Jan 2006
San Diego, CA

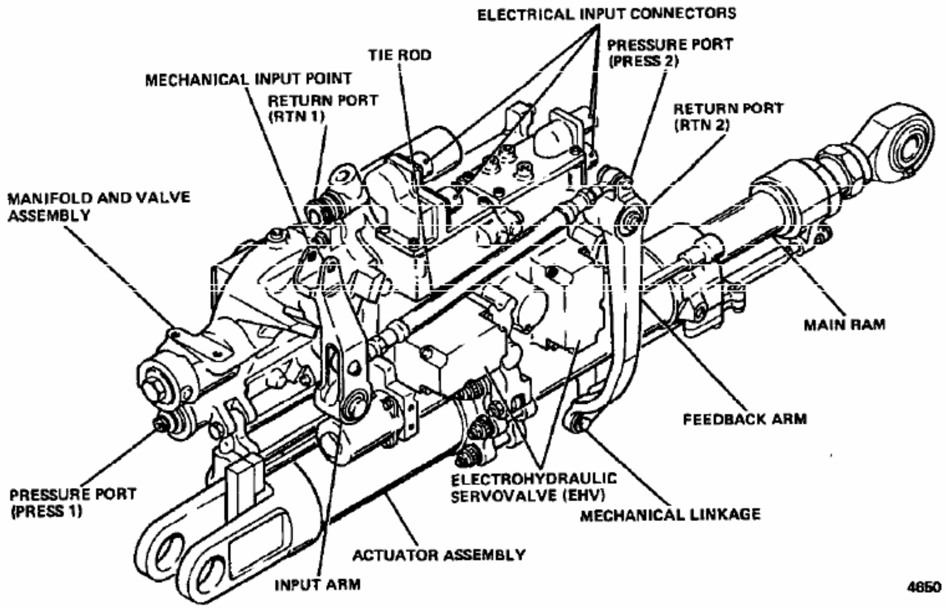
Gribble/Magno
NAVAIR-PAX Hydraulic Systems

F/A-18 C/D Stabilator Actuator

- Based on laboratory results, fluorocarbon static seals and PTFE spring energized dynamic seals in primary and secondary glands were selected.
- Rebuild kits for F/A-18 C/D stabilator actuator were developed by three seal vendors using hardware dimensions.
- Seal kits showed no external leakage and acceptable internal leakage after endurance testing. Post-test leakage was within ATP limits.
- Follow-on testing evaluated HVOF coated rod against these seals.
    - HVOF Coat short external end with WC/Co/Cr 86/10/4
    - HVOF Coat longer internal end with WC/Co 83/17
    - Ground to 8 - 16 µin Ra finish and superfinish to ≤ 2 µin Ra finish
- Leakage performance was equivalent to chrome plated rod.

F/A-18 C/D Stabilator Actuator Continued

• ECP progressing with OEM chrome rods with future possibility of HVOF coating provided by NADEP-JAX or NADEP-CP.



F/A-18 C/D Trailing Edge Flap

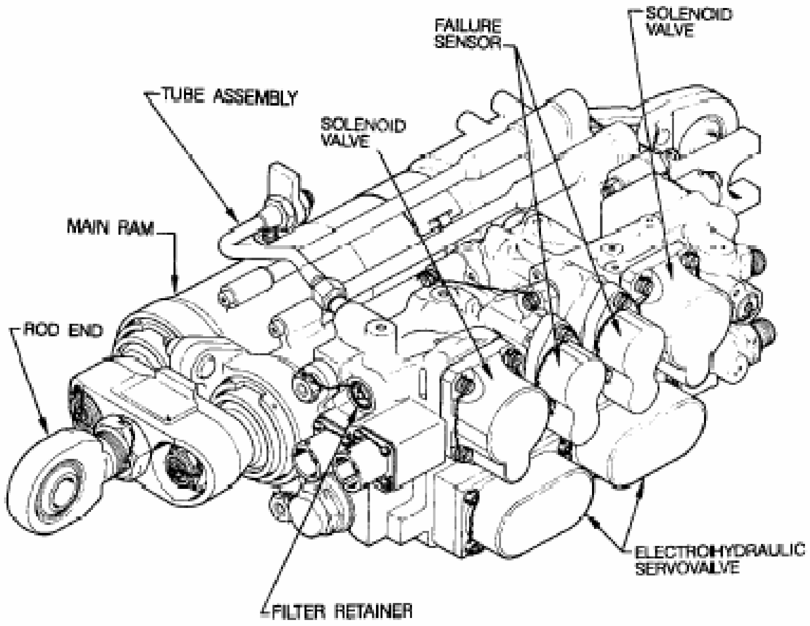
• Same dynamic and static seal materials used for TEF as proven on STAB.

• Side by side design allows one chrome rod and one HVOF rod to evaluate seals against both rod surfaces.

  • HVOF Coat OD of Piston Rod with WC/Co/Cr 86/10/4
  • Ground to 8 - 16 μin Ra finish and superfinish to ≤ 2 μin Ra finish

• Endurance testing of TEF is complete with equivalent results from chrome and HVOF.

• ECP progressing with OEM chrome rods with future possibility of HVOF coating provided by NADEP-JAX or NADEP-CP.



H-60 Main Rotor Servo-Actuator

- Investigate, evaluate, and qualify improved technology seals with HVOF rod coatings for joint Armed Services. Leveraging data from F/A-18 seal efforts to provide candidates for H-60.
- OEM performed Engineering Investigation on both Army and Navy primary and tail rotor servos to substantiate reliability data, determine root cause of leakage, and determine if additional changes would be recommended.
- Current proposal includes piston gland change, new seal material and configuration, and utilization of tungsten carbide cobalt chrome rod coating vice existing chrome.
- Proposed Qual test includes: ATP (pre and post test), fully loaded endurance testing with sand, dust, salt fog and temps from –65 to 275 degrees F.
- Effort is currently on-hold.

Questions ?